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ABSTRACT

A long-standing issue in cognitive psychology is the question of content effects upon problem-solving skills, that is, do students' problem-solving abilities generalize across specific subject matter domains? Although Piaget argued that formal reasoning strategies are independent of content, the well-known decalogs of Piaget can be interpreted as evidence that students' reasoning skills or problem-solving performance are influenced by the subject matter content of the problem. In addition, some researchers have suggested that one's familiarity (prior knowledge) with the subject matter domain influences one's level of problem-solving performance. Therefore, the effect of familiar and unfamiliar task content upon the proportional reasoning abilities of 76 ninth grade students was investigated. Students completed a 22-item test which included 12 word problems requiring proportional reasoning. These problems were constructed at three levels of difficulty, with each level containing two problems with "familiar naturalistic" content and two with "unfamiliar science textbook" content. Results show that students had greater success at solving problems with familiar than unfamiliar task content, especially for problems involving simple ratios (but not for problems involving difficult ratios). Therefore, it is recommended that teachers help students become familiar with content before they are required to solve problems involving proportional reasoning. (JN)

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THE EFFECT OF TASK CONTENT UPON PROPORTIONAL REASONING

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THE EFFECT OF TASK CONTENT UPON

PROPORTIONAL REASONING

Introduction

A long standing issue in cognitive psychology is the question of content effect upon problem solving skills, i.e. do students' problem solving abilities generalize across specific subject matter domains ? Although Piaget (1972) argued that formal reasoning strategies are independent of content, the authors would suggest that the well known decolages of Piaget can be interpreted as evidence that students' reasoning skills or problem solving performance is influenced by the subject matter content of the problem. Some researchers have suggested that one's familiarity (prior knowledge) with the subject matter domain, influences one's level of problem solving performance (Johnson-Laird, P. N., Legrenzi, P., & Legrenzi, M. S. 1972; Linn, M. C., Pulos, S., & Gans, A., 1981; Lunzer, E. A., Harrison, C., & Davey, M., 1972).

One kind of reasoning that is important to students' academic success in high school science courses, especially Physics and Chemistry, is proportional reasoning (Karplus, R., 1977; Karplus, R., & Peterson, R. W., 1970; Lawson, A. E., Karplus, R., & Adi, H., 1978).

Students in junior high school mathematics courses usually are introduced to the concept of proportions and strategies for solving problems involving proportions. The proportional reasoning problems encountered in these mathematics courses involve familiar content. But the content of many proportional reasoning problems in high school science courses is unfamiliar.

This study investigated the relationship between familiarity of task

content and proportional reasoning abilities of ninth grade students.

Task content was defined as either "familiar naturalistic" or "unfamiliar science textbook". The "familiar naturalistic" content referred to those words, processes and concepts which most students encounter quite frequently in their daily lives. "Unfamiliar science textbook" content referred to those words, processes and concepts which are found in high school science textbooks. Students in the sample were deemed to be unfamiliar with this content.

Purpose

The purpose of this study was to examine the effect of familiar and unfamiliar task content upon proportional reasoning abilities of ninth grade students.

Procedure

A written-response group test was designed, constructed and administered to 76 ninth grade students. The test consisted of twenty two items. Twelve of these were word problems which required proportional reasoning. There were five other word problems that were similar to the proportional reasoning problems , involving three real number constants and a real number unknown, but did not require proportional reasoning. Lastly there were five items that were not word problems. These involved computations of multiplication and division. The five non-proportional reasoning word problems and the five computational problems were distributed among the twelve proportional reasoning problems to break up the routine of problem solving which required the same logical structure.

The non-proportional reasoning problems were also intended to indentify whether or not students were able to discern between those problems which

required proportional reasoning and those which did not.

The twelve proportional reasoning problems were constructed at three levels of difficulty according to the ratios that were used. The three levels of difficulty were as follows:

Level I - The problems consisted of the following simple ratios 2 : 3 or 3 : 2 and 4 : 5 or 5 : 4.

Level II - The problems consisted of the ratios 4 : 15 or 15 : 4 and 5 : 18 or 18 : 5.

Level III - The problems consisted of the following ratios that involved decimal fractions, 4 : 8.9 or 8.9 : 4 and 8 : 5.4 or 5.4 : 8.

At each level of difficulty there were two proportional reasoning problems with "familiar naturalistic" content and two with "unfamiliar science textbook" content. Each problem with "familiar naturalistic" content was matched with one having "unfamiliar science textbook" content involving the same proportions, in fact the same numerical values.

The test was administered according to a set of instructions which was read and explained to the students. The students were instructed to show their work in writing and enter their final answer in the space provided. They were permitted to use calculators if and when necessary.

Scoring

The test items were dichotomously scored (1= correct, 0= incorrect) according to the students' numerical answers. The maximum score attainable was 22. The written explanations to the proportional reasoning problems were categorically scored according to the following categories:

0 - No explanation or computations given.

1 - An explanation based on guesses, or an explanation using the data haphazardly or in an illogical manner.

2 - An explanation focussing on a single arithmetic difference, uncoordinated with other differences and solving the problem by addition.

3 - An explanation making use of one ratio involved in the proportion but not applying that ratio correctly.

4 - An explanation using proportional reasoning.

The dichotomous scores of the proportional reasoning problems at the same level of difficulty and familiarity were summed and subjected to a three-way analysis of variance.

Validity and Reliability

The instrument was validated and a reliability coefficient estimate computed using the Kuder-Richardson 20 formula (r=.88). The standard error of the measurement was 1.78. The variance of the scores was 26.5 .

Findings

The results of the analyses show significant effects (at better than p= .05).

(Insert Table 1 here)

The adjusted mean score for proportional reasoning problems with familiar naturalistic content was significantly greater than that with unfamiliar science textbook content ($p < .05$). However there was a significant interaction for familiarity with levels of difficulty. When the proportional reasoning problems involved simple ratios the mean score with familiar content was significantly greater than with unfamiliar content. But when the problems involved difficult ratios, such as those at Levels II and III, the familiarity with content did not have a significant effect on the

students' achievement at solving the problems.

(Insert Figure 1 here)

When level of difficulty was considered by itself then the students' mean score for problems with ratios at Level I was significantly higher than the mean score of problems with ratios at Levels II and III. But the difference between mean scores of problems at Levels II and III was not significant.

The results for gender (independent of content familiarity and level of difficulty) show that the mean score of the male students was significantly higher than that of the female students ($p < .05$).

Students' explanations were categorically scored and the highlights are summarized below:

(Insert Table 2 here)

1) Of the total possible responses, 36% showed evidence of proportional reasoning, 13% showed evidence of using ratios incorrectly, 1% showed evidence of having used addition (i.e. another incorrect form of reasoning), 19% showed evidence of having used the data illogically and 31% had no written explanations.

2) The students showed a greater tendency to give explanations to problems with familiar than unfamiliar content.

3) The number of explanations showing evidence of proportional reasoning was greater with simple Level I problems than the more difficult problems in Levels II and III.

Implications for Instruction

The results suggest that content familiarity influences proportional reasoning. Students have greater success at solving proportional reasoning problems with familiar than unfamiliar task content. This effect seems especially evident for problems involving simple ratios but not for problems involving difficult ratios.

Science teachers need to help students become familiar with the content before they are required to solve problems involving proportional reasoning. Teachers should expose their students to varied and repeated experiences with concepts. The use of examples and non-examples of the concepts, advanced organizers, and hands-on experiences, are some ways of helping students become familiar with the content.

Further investigations are necessary to determine the relationship between students' proportional reasoning abilities, difficulty of ratios in the proportional reasoning problems, gender effects and content familiarity. Replication of this study with appropriate modifications made to control for extraneous variables such as access and ability to use calculators, and computational skill levels of the students would perhaps shed additional light on possible relationships among the variables which were investigated.

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Table 1

Three-way Analysis of Variance

Source of variation	Degrees of freedom	Mean squares	F-Ratio	p-value
Sex	1	21.827	10.329	.002
Subjects within sex	74	2.113	-------	----
Familiarity	1	3.318	10.025	.002
Sex by familiarity	1	.003	.008	.928
Familiarity by subjects within sex	74	.331	-------	----
Difficulty	2	15.386	37.375	.000
Sex by difficulty	2	.539	1.310	.273
Subjects within sex by Difficulty	148	.412	-------	----
Familiarity by Difficulty	2	3.861	18.579	.000
Sex by Familiarity by Difficulty	2	.584	2.812	.063
Subjects within sex by Familiarity by Difficulty	148	.208	-------	----
Total	455			

Figure 1. Plot of Two-way Interaction of Familiarity by Difficulty Levels

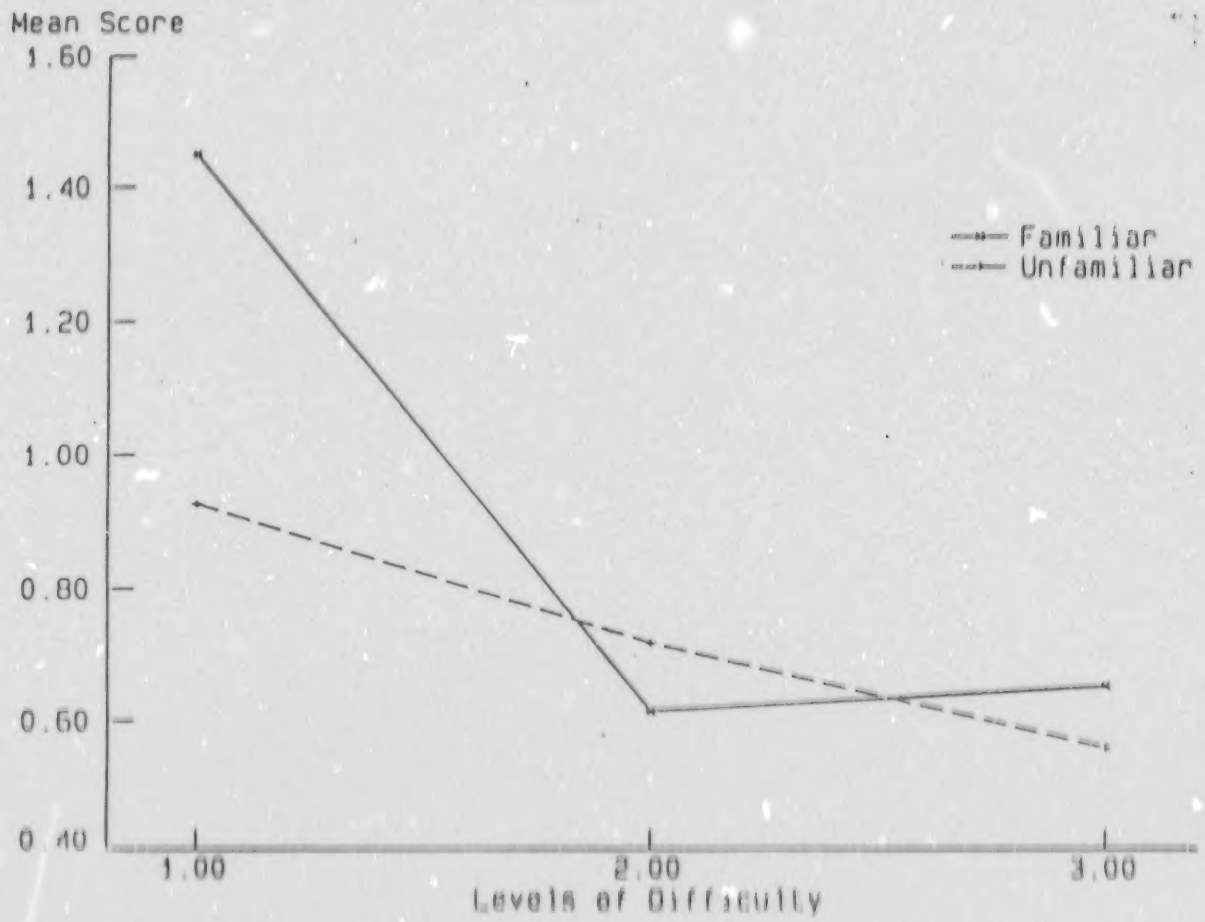

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Table 2

Frequencies of Categorical Scores

	Types of Questions [a]						
Category	AI	BI	AII	BII	AIII	BIII	Total
0 (no explanation)	27	57	37	62	40	61	284
1 (illogical)	22	28	19	21	47	39	176
2 (addition)	0	4	2	5	1	1	13
3 (incorrect use of ratio)	10	8	45	18	23	11	115
4 (proportional)	93	55	49	46	41	40	324
Total	152	152	152	152	152	152	912

Note. [a]The types of questions are classified according to the familiarity of the content and the level of difficulty of the problem. The capitalized alphabets refer to the familiarity of the task content.
A = Familiar naturalistic task content.
B = unfamiliar science textbook task content.
The Roman numbers refer to the levels of difficulty of the problems.
I = Difficulty Level I. II = Difficulty Level II.
III = Difficulty Level III.
For example, A I refers to the familiar naturalistic problems at difficulty level I and, B III refers to the proportional reasoning problem with unfamiliar science textbook content at difficulty level III.